

Experimental Study on System Reliability of Cold-Formed Steel Roof Trusses

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Abstract

This report presents a research project aimed at advancing the treatment of cold-formed steel (CFS) structural reliability in roof trusses. Structural design today relies almost exclusively on component-level design; so, structural safety is assured by limiting the probability of failure of individual components. Reliability of the entire system is typically not assessed, so in a worst-case scenario the system reliability may be less than the component reliability, or in a best-case scenario the system reliability may be much greater than the component reliability. A roof truss itself, is a subsystem with several possible failure modes that are being studied in this test program. These trusses are constructed of CFS members that nest with one another at the truss nodes and are connected by drilling fasteners through the mated surfaces, as well as having steel sheathing fastened to the top chords for lateral bracing. Presented in this paper is a series of full-scale static tests on single as well as systems of CFS roof trusses with a unique experimental setup. The test specimens were carefully monitored to address multiple failure modes: buckling of the top chord, buckling of the truss webs, and any connection failures. This report includes the details of the test program and the experimental results.

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Introduction

System reliability is a well-developed topic from a theoretical perspective, however there are still many barriers to its implementation in cold-formed steel (CFS) design. Direct simulations to obtain the system probability of failure while considering strength, material properties, and applied loads as random variables is one possible approach. However, the required statistics are often not available and high reliability computational simulations of a real building to collapse remain elusive, with many of these simulations requiring a Monte Carlo approach. Element based load resistance factor design (LRFD) has served the structural engineering design community well with its conceptual simplicity, but its equivalent for complex structural systems such as buildings or even bridges, or for simpler subsystems such as walls and roofs, are not well developed enough, resulting in the reliability of an element (i.e. a CFS stud member) being misaligned with the reliability of the system (i.e. several studs connected with bridging and sheathing to make a load bearing wall). With that in mind it should be noted that the goal of this research is to advance the treatment of CFS structural reliability in roof trusses and to ultimately move that much closer to a solution to system reliability in their structural design, where this paper will present the results gathered from a series of full scale static tests on single as well as a system of CFS roof trusses with a unique experimental setup.

Test Setup

Test Setup for Single Truss Tests

Trusses are constructed of CFS members that nest with one another at the truss nodes and are connected by self-drilling screw fasteners through the mated surfaces. Steel or wood sheathing is thoroughly fastened to the truss top chords and provide lateral bracing. A roof truss itself, is a subsystem with several possible failure modes that will be studied in this test program. The testing equipment that will be used consists of 12 hydraulic cylinders that can apply a uniform downward pressure to the top chord of the truss. Figures 1 and 2 respectively illustrate the testing setup for single truss specimen manufactured by Aegis and TrusSteel companies. Figure 3 is a photograph taken during our first trial test for the TrusSteel single truss tests.

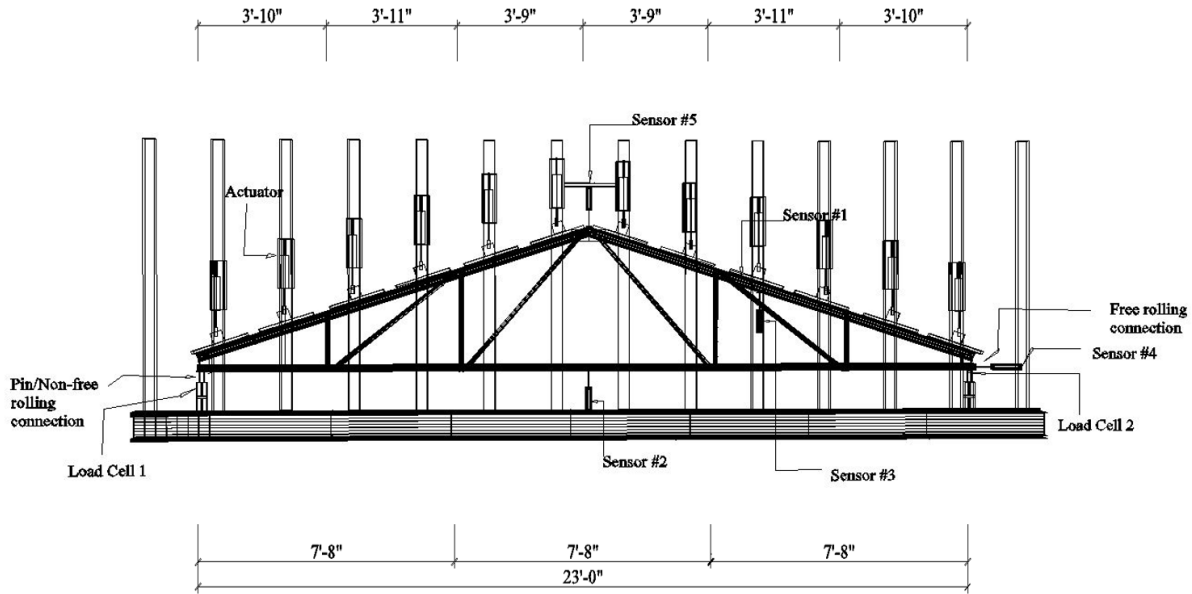


Figure 1: Test Setup for Aegis Single Truss

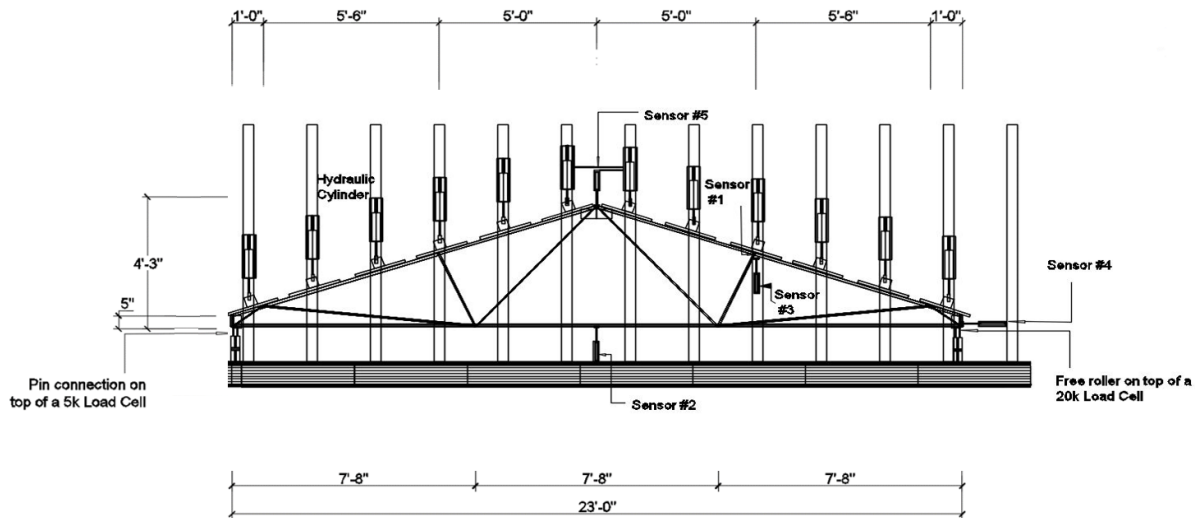


Figure 2: Test Setup for TrusSteel Single Truss

The single truss setup used three sensors to measure the vertical displacement along the top chord and bottom chord. One vertical sensors was located on the bottom chord (sensor #2). Another sensor was placed at the truss' peak (sensor #5) and another was located along the top chord (sensor #3). The fourth sensor was located at the rolling connection of the truss (sensor #4) and used to record the horizontal displacement. The last sensor was located on the top chord (sensor #1) near another sensor but was used to record the out-of-plane displacement of the truss.

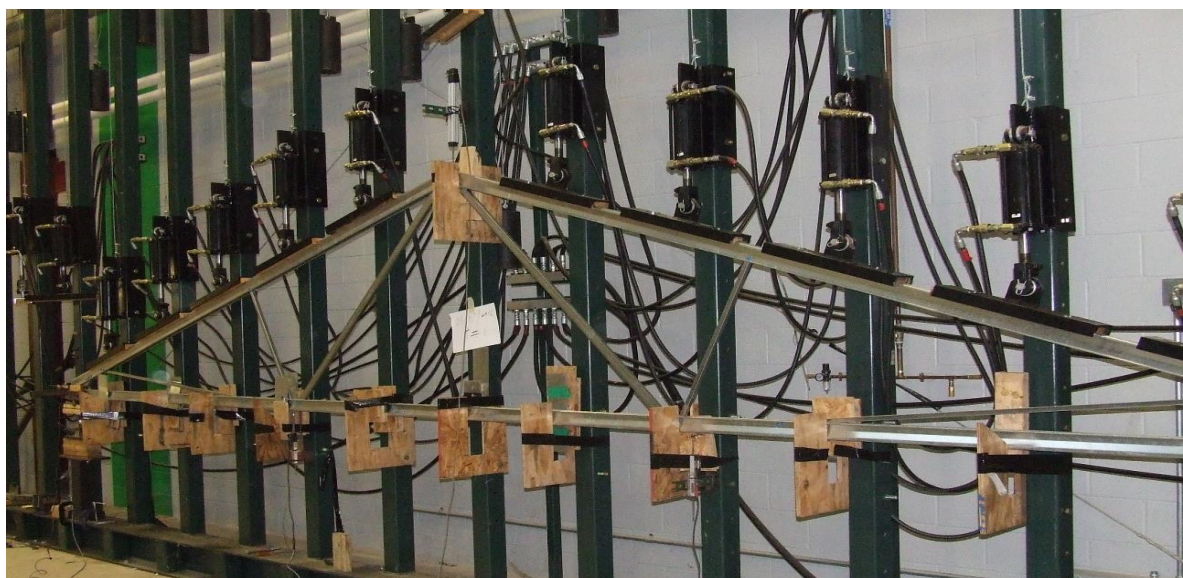


Figure 3: TrusSteel Test Setup

A series of full-scale static tests on CFS roof trusses with a unique experimental setup were conducted in the University of North Texas' structural testing laboratory. The test specimens were carefully monitored and three main failure modes were observed: buckling of the top chord, buckling of the truss webs, and any connection failures. Table 1 lists the testing matrix that was used to test the two different truss profiles in this research and Figure 3 is a photograph taken during our first trial test for the single truss tests.

Table 1: Test Matrix

Truss Profile	System Test	Truss Slope	Truss Span	Force Profile	Test per Profile	Trial Test	Extra Tests
TrusSteel	single truss	4:12	23 ft.	gravity	3	1	1
	2 trusses connected w/ metal b-deck sheathing				3	1	1
Aegis	single truss	4:12	23 ft.	gravity	3	1	1
	2 trusses connected w/ metal b-deck sheathing				3	1	1

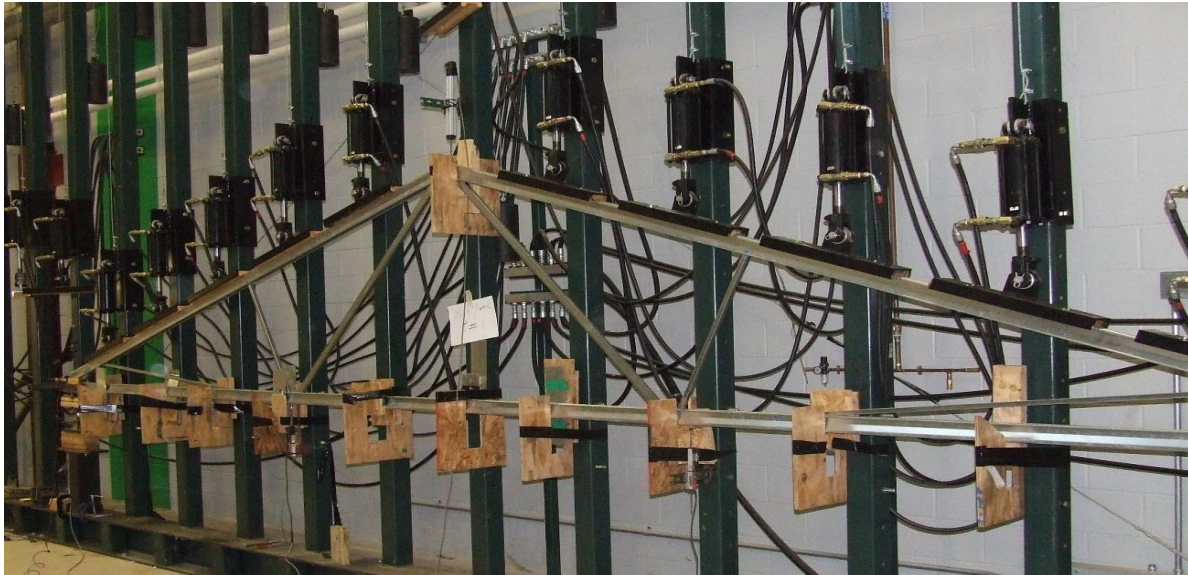


Figure 4: TrusSteel Test Setup

Test Setup for Truss System

In addition to the single truss tests, as specified in the truss testing matrix in Table 1, system tests were also performed using two trusses that were primarily connected using CFS steel corrugated decking. Figure 5 is a photograph taken of the system truss tests.

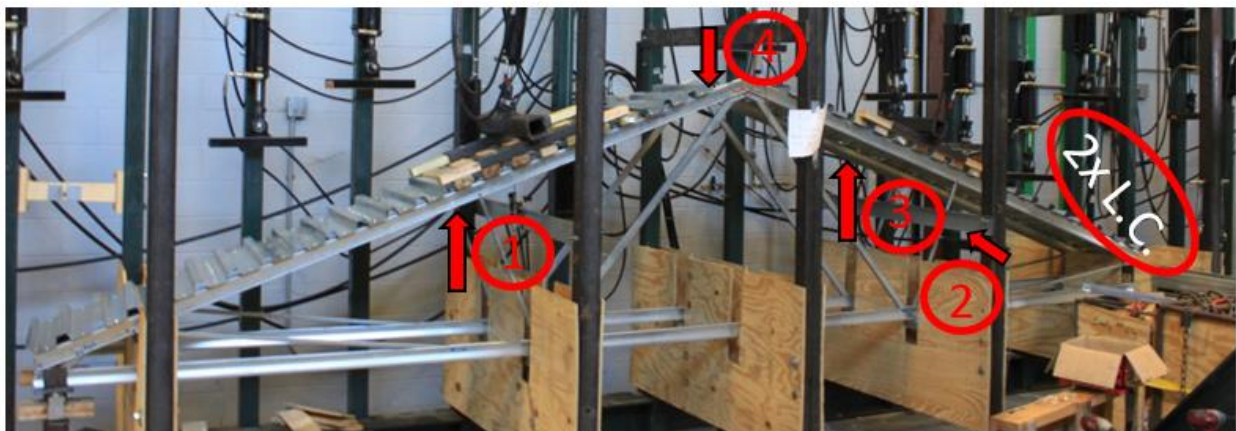


Figure 5: System Truss Setup TrusSteel

Figure 5 shows the test setup for the system tests, as well as how the trusses were braced to limit out-of-plane movement. The system test setup differed from the single truss setup in that it used a different loading pattern. The system trusses used two-point loading systems located at a third of